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REVEALING THE F

NASA-CR-192922

MAGELLAN

(NASA-CR-192922) REVEALING THE FACE OF VENUS: MAGELLAN (JPL) 28 p

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A Global View

Venus, our closest planetary neighbor, shares a common ancestry with Earth: Both planets formed about the same time and from the same gaseous nebula. Both planets have evolved in the same area of our solar system and display remarkably similar physical characteristics. Venus and Earth share like surface histories, both having been shaped by volcanism, tectonic activity and meteorite bombardment. Since Venus is the planet most like Earth, what we learn about our "sister planet" could be critical to our understanding of the processes that underlie Earth's life-sustaining environment. Data from the National Aeronautics and Space Administration (NASA) Magellan radar-mapping mission are testing many of our basic ideas about planetary evolution — by making us reconsider theories about how mountains form, why volcanoes erupt and why the process of plate tectonics occurs only on Earth and not (to our knowledge) elsewhere. Previous missions by United States and Soviet spacecraft, along with observations from ground-based radar, have provided tantalizing views of Venus' large-scale surface features. Soviet landers transmitted images and other data from Venus' surface before succumbing to the searing temperature (up to 470 degrees Celsius) and crushing pressure (90 times that at Earth's surface). These early glimpses provided us with a vast store of knowledge. But only Magellan has captured a global view of Venus — an image that truly enhances our understanding of Earth's sister planet.

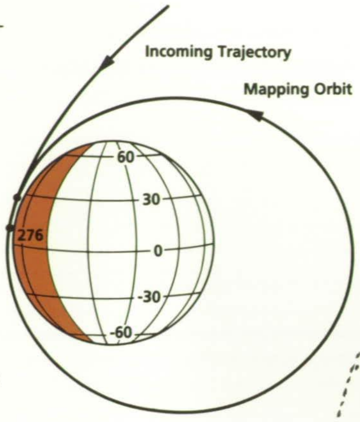
This hemispheric view of Venus' surface (also shown on the cover) was created by mapping mosaics of images captured by Magellan onto a computer-simulated globe. The simulated color — used to enhance small-scale features — is based on color images acquired by Soviet spacecraft in the early 1980s.

Magellan's Quest

Magellan was launched from NASA's Kennedy Space Center aboard the Space Shuttle Atlantis on May 4, 1989. On August 10, 1990, the spacecraft maneuvered into an elliptical, nearly polar orbit around Venus; radar mapping began on September 15, 1990.

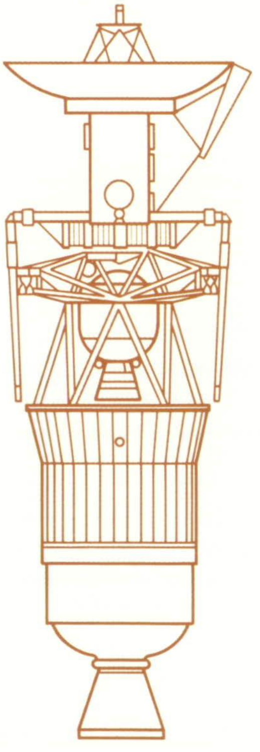
Over the following 243 Earth days (one complete Venus rotation), Magellan achieved and even exceeded its primary objective: to map 70 percent of the planet's surface. After three complete 243-day cycles, the spacecraft has mapped some 99 percent of Venus' surface — an area three times as large as Earth's combined continental land masses. The amount of digital imaging data Magellan has returned is more than twice the sum of returns from all previous United States planetary missions.

On September 15, 1992, Magellan began a fourth 243-day cycle: a global gravity survey that will help scientists to map the internal structure of Venus.



Following launch, Magellan traveled one-and-a-half times around our Sun and covered 595 million kilometers before reaching Venus. Upon arrival, Magellan's solid rocket motor fired, slowing the spacecraft. Venus' gravity then captured Magellan into a mapping orbit.

ORIGINAL CONTAINS COLOR ILLUSTRATIONS



The Magellan spacecraft and inertial upper stage. The spacecraft itself is 6.4 meters tall, 3.7 meters across (high-gain antenna diameter) and weighs 3,460 kilograms.

THE SPACECRAFT

Building Magellan was an exercise in efficiency; the spacecraft incorporates several existing hardware designs and includes spare parts from a number of other missions. Magellan's solar panels use solar energy to generate the 1,200 watts of electrical power required to operate all the onboard equipment. Multilayered thermal blankets and a special white paint offer protection from the extremes of heat and cold the spacecraft experiences in outer space and planetary orbit. Despite such precautions, exceptionally high spacecraft temperatures periodically require pointing Magellan's large dish antenna toward the Sun — so the rest of the vehicle can cool off in the antenna's shade.

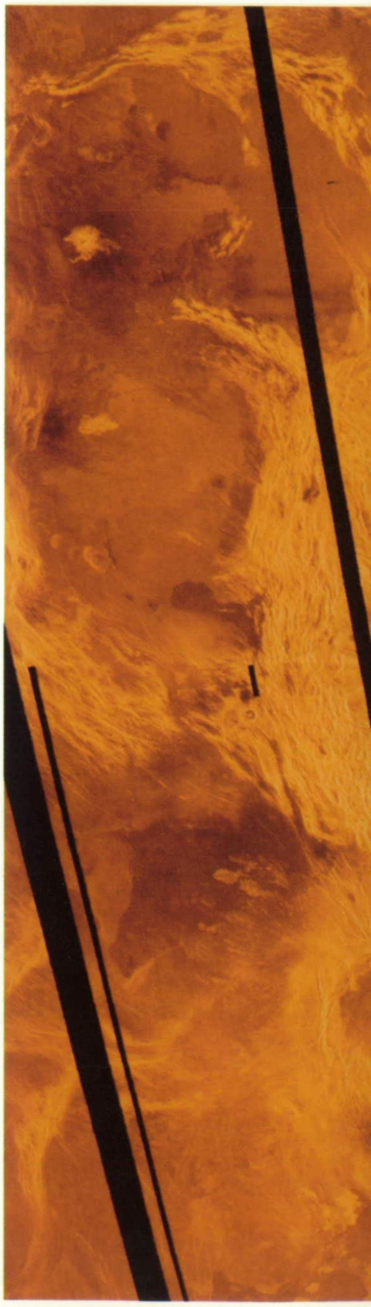
Magellan's large antenna — a spare from the Voyager mission — transmits science and engineering data back to Earth by radio at a peak rate of 268.8 kilobits per second, the highest data rate ever used. The data are received on Earth by the large tracking antennas of NASA's Deep Space Network (DSN) stations in Goldstone, California; near Madrid, Spain, and near Canberra, Australia. The DSN in turn transmits the downlinked information to the Jet Propulsion Laboratory (JPL) in Pasadena, California.

In low Earth orbit, the Space Shuttle Atlantis deploys Magellan on its 15-month journey to Venus. Unlike its namesake, the explorer Ferdinand Magellan — who never survived his epic travels — the Magellan spacecraft easily completed its voyage to Venus. It then began its real mission — to map the surface of Earth's "sister planet."

Venus Unveiled

The Venus unveiled by Magellan shows a tortured surface shaped by geological violence throughout its history — tectonic deformation, volcanism and impact cratering. At least 85 percent of Venus is covered by volcanic rock — mostly lava flows that form the planet's vast plains. Much of the remaining surface consists of mountainous areas that appear to have been deformed repeatedly by geologic activity. Lacking rainfall, oceans and strong surface winds, Venus seems to experience very little erosion; surface features endure for long periods of time.

Artemis Corona, spanning 2,100 kilometers in diameter, is the largest such feature on the surface of Venus. Unique to Venus, coronae may reflect deep-seated interior processes that uplift and deform the surface and cause volcanism.



Alpha Regio was the first feature identified in Earth-based radar images of Venus. Its complex terrain of intersecting ridges, troughs and flat-floored valleys was probably formed by tectonic processes. The darker patches are low areas filled with smooth volcanic lava. The black strips in this and other images represent gaps in radar data.

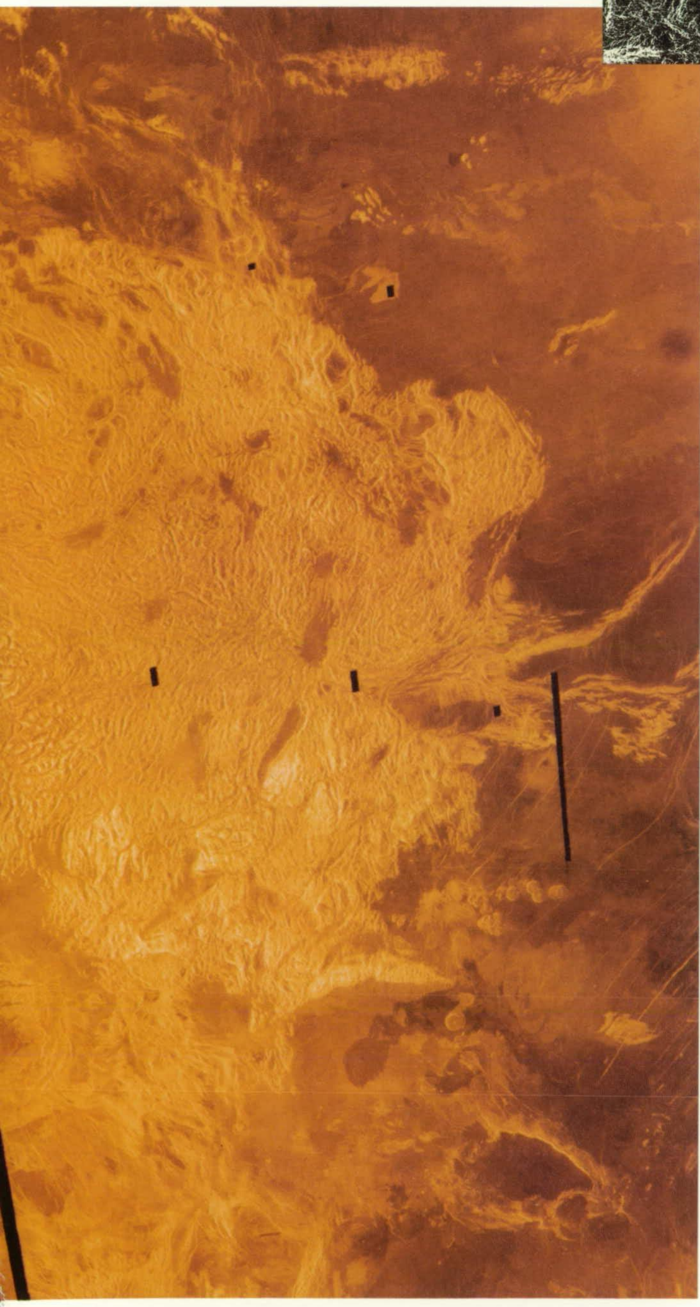
PLATE TECTONICS

On Earth, large crustal "plates" drift slowly across the surface, driven by currents of hot rock moving below the crust in a zone of dense material called the mantle. Where the plates separate from each other, they leave a rift that fills with basaltic magma (molten rock) welling up from the hot mantle. Because the continents are made mostly of thicker, lower density material, they tend to float — like icebergs in water — at a higher level than the basaltic material surrounding them. The lower, denser regions form the floors of Earth's oceans. Thus we find on Earth a basic difference between the height of continents and ocean basins.

On Venus, by contrast, plate movement is not evident and surface heights are less extreme. There are exceptions, however: The steep trenches of Diana and Dali Chasmata, *for instance, which are located in the Aphrodite Terra highlands near Venus' equator, rival the great oceanic trenches on Earth. These Venusian trenches measure some 50 kilometers across, with raised rims several kilometers high at one edge, followed by a steep slope that plunges more than 7 kilometers to the bottom.*

Tessera terrain, within Alpha Regio, is a chaotic mixture of ridges, troughs and depressions suggesting numerous episodes of deformation. Tessera (Greek for "tile") was named by the Soviets after such terrain was seen in radar imagery from their Venera 15 and 16 missions in the 1980s.

Although Venus has neither running water nor rainfall, the high surface temperatures would probably cause the slopes to relax gradually over millions of years if not maintained by continuing tectonic forces. Magellan images have yet to reveal irrefutable evidence that Venus remains geologically active, but features like these cause scientists to strongly suspect that it is.



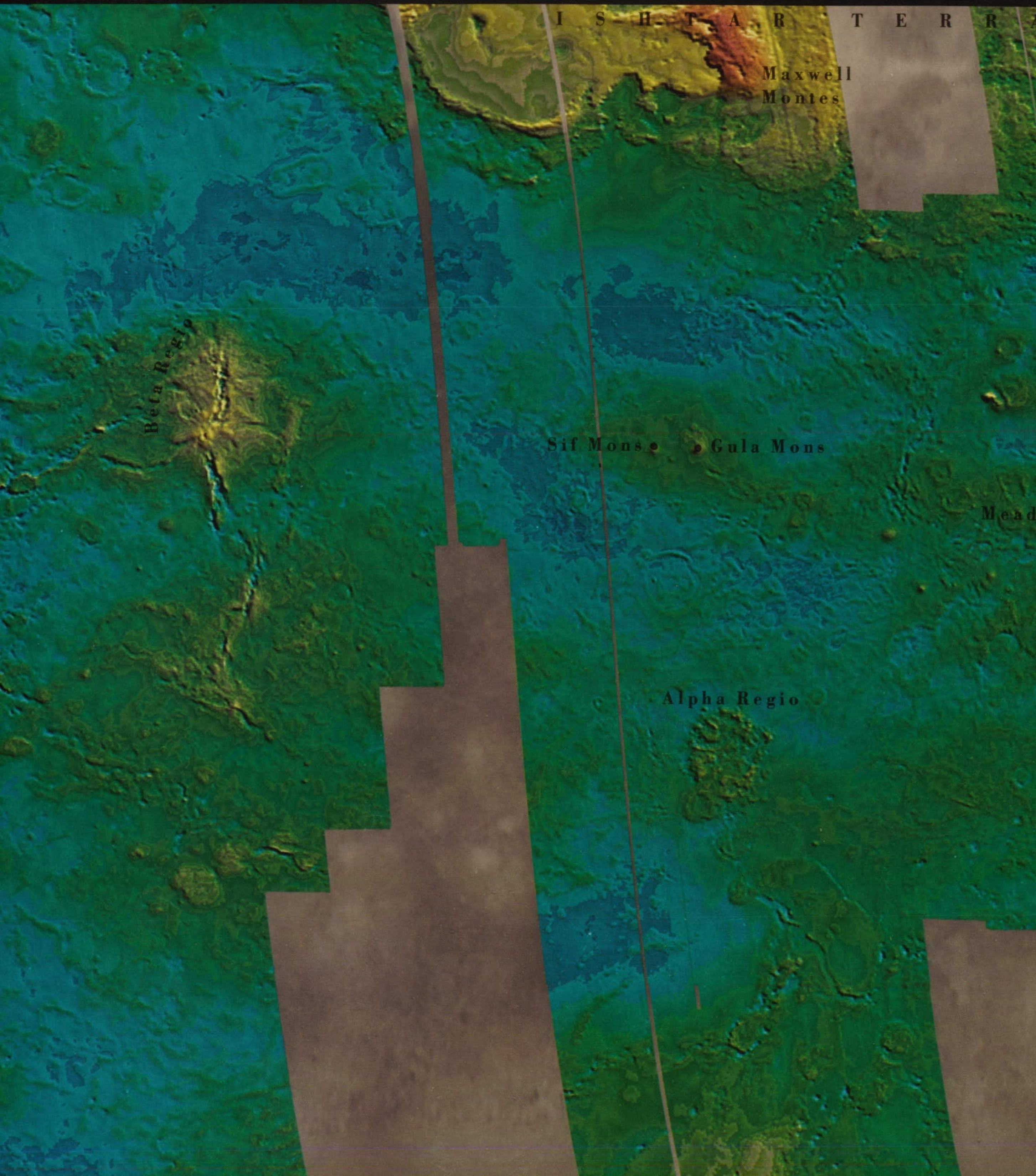
VOLCANIC ACTIVITY

Lava flows — emerging from volcanoes, cracks in the crust and depressions in the surface — offer the most obvious evidence that volcanic activity has occurred on Venus. While many of these flows are only a few kilometers long, larger ones extend for hundreds of kilometers and may have resulted from either very fluid material or very high rates of eruption. Spreading lavas have flooded and filled low-lying regions on Venus, creating extensive plains. Some plains appear bright in radar images, but most are dark, indicating a smooth surface. Many of these plains areas do not feature the distinctive lobate (curved) boundaries that identify the front of a lava flow; nevertheless, their smoothness and location near volcanic landforms strongly suggest they were indeed formed by volcanic flows.

VENUS AND EARTH: SISTER PLANETS

Having evolved in the same area of our solar system, Venus and Earth claim a common ancestry and parallel surface histories. The so-called "sister planets" even possess a physical similarity in terms of size and mass. In terms of size, Venus' equatorial diameter is 12,104 kilometers, just a fraction less than Earth's equatorial diameter of 12,755 kilometers. In terms of mass, Venus' relative measure is 0.82; the slightly heavier Earth's, of course, is 1.0. In addition, Venus and Earth have nearly equal planetary densities: 5.11 and 5.52 grams per cubic centimeter, respectively.

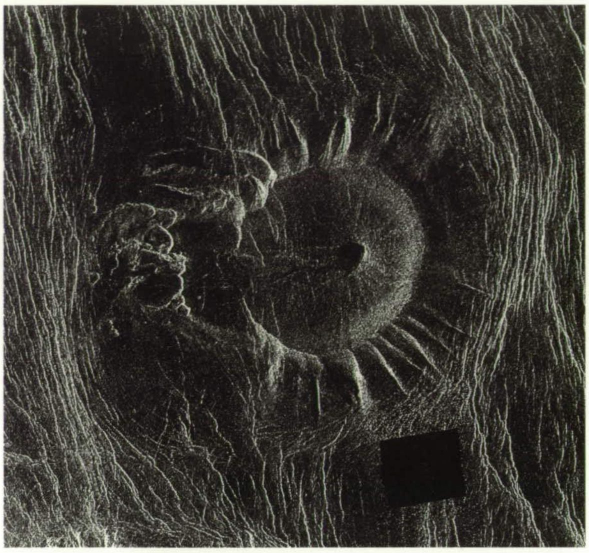
However, further examination reveals that Venus and Earth are "fraternal" rather than "identical" siblings. Indeed, a comparison of some basic characteristics shows that these sisters are as different as they are alike.



Parameter	Venus	Earth
Atmospheric composition	Carbon dioxide, nitrogen	Nitrogen, oxygen
Atmospheric pressure	92 Bars	1 Bar
Distance from Sun	108 million kilometers	150 million kilometers
Rotation period	243 Earth days	1 Earth day
Rotation type	Retrograde	Direct
Surface temperature	750 Kelvin	300 Kelvin

On this topographic map, the heights of a portion of Venus' surface features — which are derived from altimetry data — range from blue for low elevations to red for the highest areas. Gray regions in the image represent gaps in data. The large highland (gold area) to the north is Ishtar Terra and contains Maxwell Montes, Venus' highest peak. Aphrodite Terra's highlands are draped along the equator (right of center).

Volcanoes are everywhere on Venus: At least 100,000 small "shield" volcanoes (shaped like inverted shields), each less than about 15 kilometers in diameter, have been detected in Magellan images. A similar number of these small shield volcanoes exist on Earth, primarily in the Atlantic and Pacific ocean basins. Many of the Venusian features have summit pits from which emerging lava has built up the volcanoes, flow after flow. Most of the small volcanoes are found in large clusters averaging 100 to 200 kilometers in diameter. The clusters may represent "hot spots" where material from the mantle of Venus broke through the crust to the surface.



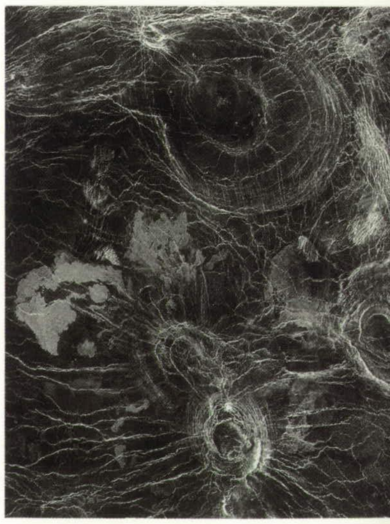
This unusual volcanic feature measures about 66 kilometers across the base and has a relatively flat, concave summit 35 kilometers in diameter. Ridges and valleys radiating from its sides give the volcano a fluted appearance resembling a tick. The western rim has been breached by smooth lava flows (dark areas) from the summit pit. The black square in the image represents a gap in radar data.

Hundreds of larger volcanoes with flows extending for hundreds of kilometers also appear on Venus. The shapes of medium-sized volcanoes have evoked comparisons to familiar items — "ticks" and "pancakes." The "legs" of the tick-like features may represent lava flows, small rifts or landslides; the pancake-shaped features probably formed from thick lavas that oozed from beneath Venus' surface.

Magellan scientists suspect that a number of volcanoes on Venus are still active. Clouds from a volcanic eruption, however, are not visible to radar, Magellan's instrument of observation. As a result, scientists must look for changes on the surface of Venus — by comparing images from the different 243-day mapping cycles.

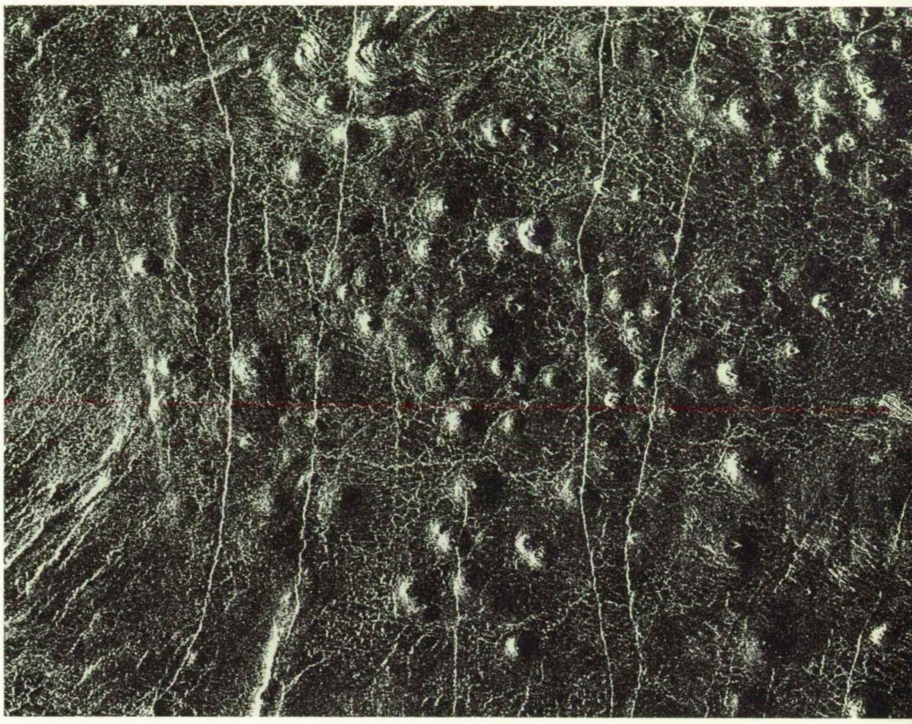
Even if Magellan could see volcanic eruptions on Venus, the spacecraft would not witness the colorful fountains of fire that are typical of eruptions on Earth. Such

Unique to Venus, arachnoids are circular-to-ovoid features with concentric rings and outward-extending fractures. These remarkable features, which are similar to coronae, may precede the latter's formation. The arachnoids in this image range in diameter from 50 to 230 kilometers. The rough lines (bright areas) extending for many kilometers may have been caused by molten rock seeping into surface fractures. Radar-bright lava flows dominate the center of the image.



spectacles are caused by the release of gas as molten rock nears the surface. On Venus, the high atmospheric pressure prevents gas from escaping; molten rock does not readily erupt into a spray of bright droplets. On the whole, volcanism on Venus may be a calmer process, producing topographically lower volcanoes than those on Earth.

Venus' volcanism may also be responsible for the long, sinuous channels snaking across the planet's plains. One of these channels (pictured on page 22) extends nearly 7,000 kilometers and is the longest such feature ever observed. At a glance, the channels suggest river beds, but Venus is currently far too hot for liquid water — and there is as yet no evidence that the channels date from a previous period when the temperature might have been different. Instead, the Venusian channels might have resulted from outpourings of lava hot enough to carve through solid rock. Known as thermal erosion, this process is also believed to have occurred on Earth's Moon.



Shaped like inverted plates or shields, shield volcanoes are the most abundant geologic features on Venus, numbering hundreds of thousands or even millions. Only Earth has an equally large number of small shield volcanoes. The volcanoes in this image range from 2 to 12 kilometers in diameter.

Other features of volcanism include giant calderas — depressions usually found at the peaks of volcanoes. Created when molten rock recedes from subsurface reservoirs and causes their roofs to collapse, calderas on Earth span only a few kilometers in diameter. On Venus, calderas are far more expansive, sometimes over a 100 kilometers in diameter.

Apparently unique to Venus are large, circular features called "coronae," which are hundreds of kilometers across and are encircled by rings of ridges. Coronae may result from deep-seated interior processes that uplift and deform the surface.

Synthetic Aperture Radar: A Different Look

A t first, the images delivered by Magellan's synthetic aperture radar (SAR) look similar to traditional aerial photographs. But closer inspection reveals important ferences. For one, certain surface areas may appear ight" in a radar image, but that is not necessarily so in hotograph. Rough surfaces and forward-tilting slopes appear bright in a radar image since they reflect back to the spacecraft more of the energy from the microwave pulses. Surfaces that are smooth or tilt away from the radar appear darker because the radar beams are reflected away and less energy bounces back to the antenna.

east-moving lava flow aches a ridge belt and pools a vast, rough (bright area)),000-square-kilometer desit. Ammavaru, the volcanic urce, lies almost 300 kilomes to the west.

Other characteristics distinguish radar images from conventional photographs. Since photographs are made with light, the light source (the Sun, for instance) is important to the picture that emerges. But since SAR carries its own radiation source and does not need either the Sun or any other light, images can be generated from data gathered in any manner — at night and through clouds.

dar images are usually shown in shades of gray: darker ades indicate areas where less radar energy is reflected ck to the spacecraft; brighter shades indicate that more ergy is returned. Color may be added to SAR images to hance specific features.

Pancake-shaped domes, located on the eastern edge of Alpha Regio in Venus' southern hemisphere, probably formed when thick lava oozed out onto the planet's surface. The domes average 25 kilometers in diameter and reach a maximum height of 750 meters.

Venus includes several continent-sized highland regions, which are distinguished by intensely deformed mountain ranges. The southwest face of Maxwell Montes, the highest mountain on Venus, reaches almost 11 kilometers above the average height of the surface — impressive by any standard.

A yet unsolved mystery involves the elevated areas on Venus, particularly those rising above 2.5 kilometers. The surface material at these elevations often appears unusually bright in radar images, a characteristic similar to the reflectivity of a moist soil cover. Again, of course, liquid water cannot exist on Venus — so beyond knowing that it reflects radar energy well, this bright material remains unexplained. One current theory holds that the material comprises small grains of metallic mineral such as magnetite (iron oxide that has not completely transformed into rust) or pyrite (a form of iron sulfide embedded in or coated on basaltic rock, also known as "fool's gold").

IMPACT CRATERING

Magellan images have revealed more than 900 impact craters, distributed randomly over the surface of Venus. Most of these craters have not been modified by erosion.

Venus' atmosphere plays a significant role in the planet's cratering process: There is a dearth of craters smaller than about 2 kilometers in diameter. Projectiles that normally would produce such small craters vaporize or break up during their passage through the dense atmosphere. The exceptions are crater clusters, which occur when large projectiles shatter just before impact, showering an area with meteoritic fragments.

Studies of the relationship between Venus' atmosphere and its abundance of craters have helped scientists to determine that the planet's atmosphere has been in place for several hundred million years, comparable to the average surface age of Earth's continents.

Another atmospheric interaction is evident in Magellan images: Meteorite impact may produce intense atmospheric shock waves that, in turn, create dark or bright halo-like features around some craters. Also, large, arc-shaped features extend to the west of quite a few craters, suggesting an interaction with global atmospheric winds in which the rapidly rotating atmosphere distributes impact-ejected material downwind (to the west). Venus' atmosphere, like the planet itself, rotates to the west.

WIND STREAKS

Magellan has revealed many features on Venus related to wind on the planet's surface. Wind "streaks" are often located near topographic barriers such as ridges. Impact craters may have provided the material moved by the wind. The orientation of the streaks indicates that the winds tend to blow toward the equator from the northern and southern hemispheres. Study of the streaks contributes to the understanding of Venus' global wind patterns. Any changes in the streaks that are evident when comparing data from several mapping cycles will help scientists to determine the rate at which the wind moves material across the surface.

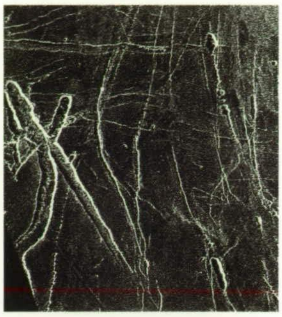
Left: Wind streaks and a dune field lie in a valley between Ishtar Terra and Meshkenet Tessera in Venus' northern hemisphere. The dunes range from 0.5 to 10 kilometers in length and are about 0.2 kilometer wide. The orientation of the dunes and wind streaks in the southern part of the field indicates a northeasterly wind flow — shifting to a westerly flow in the northern part of the field.

ANGLING FOR THE BEST LOOK

Mapping cycles subsequent to the first 243-day period have allowed the use of different observation strategies and different "look" angles that constantly increase our ability to interpret Magellan's innumerable images. During the first mapping cycle, the angle from which Magellan looked at the Venusian surface varied according to its position — from high above the planet over the north polar region, to close to the surface over the equator. This varied mapping strategy allowed Magellan to acquire the highest resolution data possible, yet with relatively constant image quality.

Looking at the same target from two different angles results in "stereo pairs": a three-dimensional view that is at once dramatic and at the same time enables the best scientific interpretation of geological features.

Still, since varying angles make comparisons difficult — because different areas are imaged in different ways — the second mapping cycle employed a constant mapping angle that has markedly improved scientists' ability to compare images from regions in diverse latitudes.

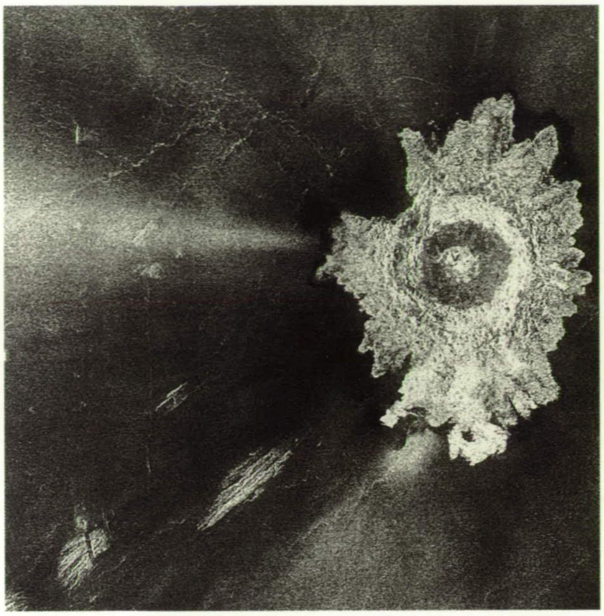


Shown above and at right are two Magellan radar images of part of Venus' Lavinia Region. Above, the north–south trending trough features a bright side at right and a dark side at left; at right, the pattern is reversed. The radar was looking from the left in the image above and from the right in the image at right.

This 72-kilometer-diameter impact crater is remarkable for extensive flows that appear to have traveled over 300 kilometers from the crater walls. The rough flows (bright areas) lie in striking contrast to the smooth, underlying plains (dark areas) and may represent material melted by impact.

POLE POSITION

Mapping a planet's surface requires the determination of two measurements — rotation period and north pole direction. Astronomers have long measured Earth's rotation period and the direction of its North Pole in relation to the stars. And, for over a century, zero degrees longitude on Earth has been placed on an imaginary line running due north–south through the observatory in Greenwich, England, thereby establishing the permanent latitude and longitude coordinates for our planet.



The 30-kilometer-diameter Adivar Crater, named for Turkish educator and author Halide Adivar, features a rare, bright, jet-like streak extending to the west for over 500 kilometers. The streak may be the result of the interaction among high-speed winds in the upper atmosphere and crater materials (the meteorite, the surface material ejected on impact or both).

Venus rotates in a retrograde direction — that is, opposite to the direction of Earth's rotation. On Venus, longitude is measured from zero to 360 degrees, only to the east; there is no west designation. The prime meridian, or zero degree longitude, passes through the central peak of a small crater named Ariadne, which lies just south of 44 degrees north latitude.

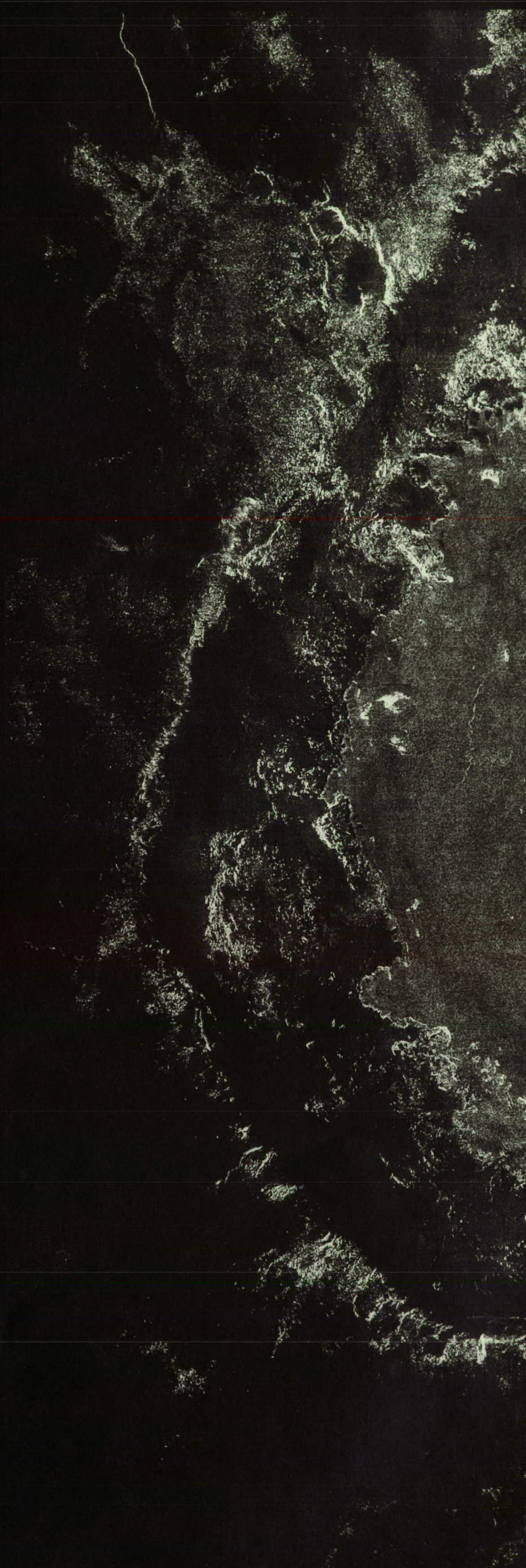
Throughout the 1980s, radar telescopes at Arecibo, Puerto Rico, and Goldstone, California, collected increasingly higher grade radar images of Venus. In addition, radar instruments aboard the Soviet Venera 15 and 16 spacecraft mapped Venus' northern hemisphere, providing data complementary to those obtained from the ground-based telescope observations. Based on these data, the International Astronomical Union (IAU) determined that Venus rotates once every 243.025 Earth days — and that the direction of Venus' north pole is 272.69 degrees right ascension and 67.17 degrees declination in J2000 astronomical coordinates. (Right ascension and declination are longitude and latitude,

Venus, the planet, was named for the ancient Roman goddess of love and beauty. Like its mythological namesake, thoughts of the planet initially conjured up romantic images. Also like its namesake, a closer look at the planet has since revealed a complex, mysterious personality.

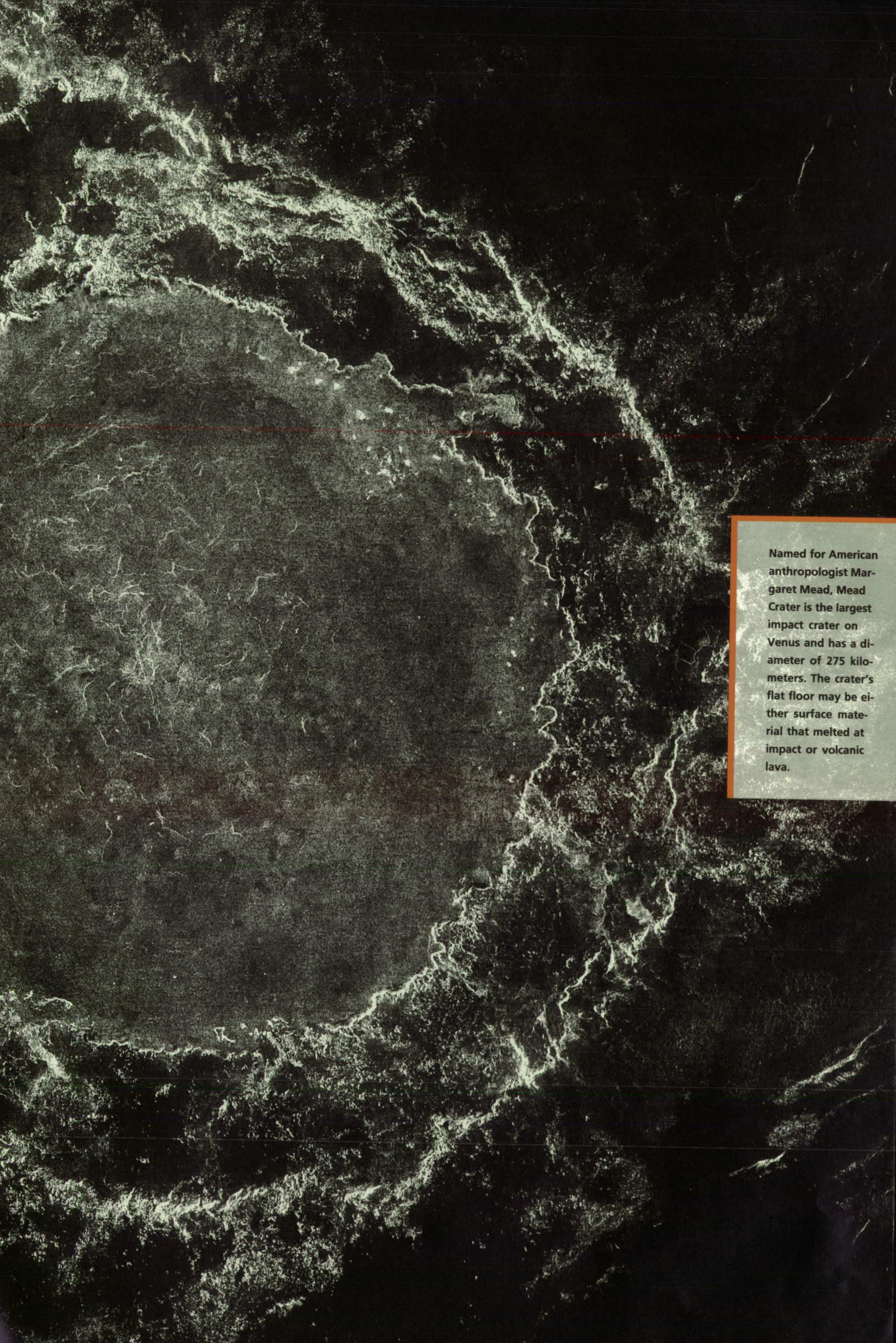
Women, Real and Mythological

The International Astronomical Union (IAU), the organization responsible for naming planets and satellites, has adopted a theme for naming features on Venus: women, both real and mythological, from all over the world. Each feature name consists of two parts: a female first name, such as *Aphrodite* (the Greek goddess of love), plus a feature-type designation, such as *Terra* (for highland). Only three features on Venus do not follow the IAU theme: the regions named *Alpha*, *Beta* and *Maxwell (for radar scientist James Maxwell)*, which were christened before the naming convention was adopted.

Feature	Definition	Category
Chasmata	Canyons	Goddesses of hunt or moon
Colles	Small hills, knobs	Goddesses of sea
Coronae	Ovoid-shaped features	Goddesses of fertility
Craters (large)	Craters	Famous women
Craters (small)	Craters	Female first names
Dorsa	Ridges	Goddesses of sky
Lineae	Elongate markings	Goddesses of war
Montes	Mountains	Goddesses, miscellaneous
Paterae	Irregularly shaped craters	Famous women
Planitae	Low plains	Mythological heroines
Planum	High plain	Goddess of prosperity
Regiones	Areas of moderate relief	Giantesses or titanesses
Rupes	Scarps	Goddesses of hearth and home
Terrae	Highlands	Goddesses of love
Tesserae	Polygonal ground; tiles	Goddesses of fate or fortune
Tholi	Domical hills	Goddesses, miscellaneous



The Deep Space Network's 70-meter-diameter antenna in Goldstone, California, began receiving Venus radar data from Magellan on August 16, 1990. The Goldstone antenna, along with antennas near Madrid, Spain, and Canberra, Australia, downlinked Magellan data almost flawlessly and at a phenomenal rate: 268.8 kilobits per second for two hours out of every three.



Named for American anthropologist Margaret Mead, Mead Crater is the largest impact crater on Venus and has a diameter of 275 kilometers. The crater's flat floor may be either surface material that melted at impact or volcanic lava.

The four separate craters in this photograph — with rims nearly touching each other — were probably caused when a large meteoroid was shattered as it passed through Venus' dense atmosphere and showered the area with meteorite fragments.

respectively, on a map of the sky as seen from Earth. J2000 is the correct astronomical coordinate system for sky maps in the year 2000.)

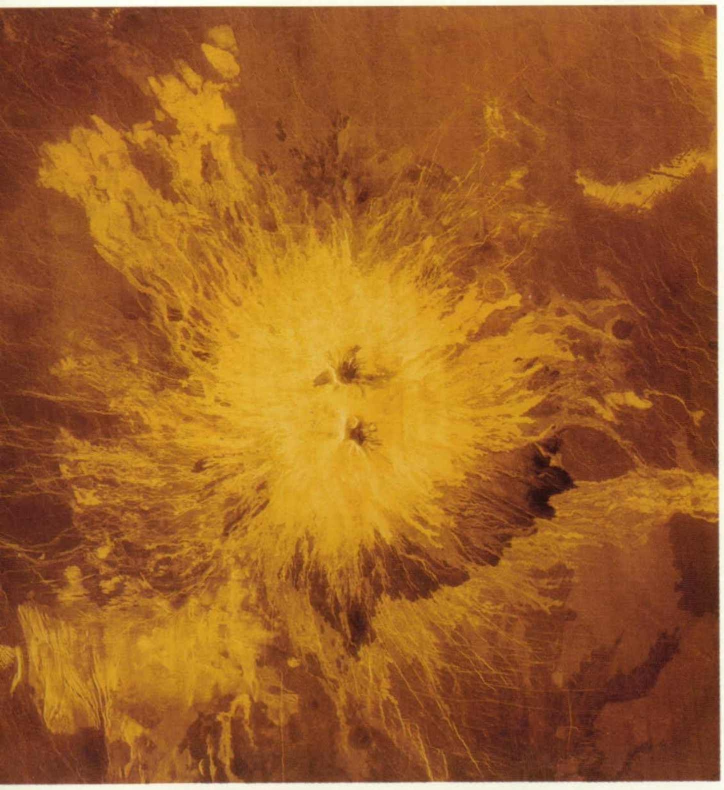
Magellan has made key contributions toward the refinement of a coordinate system for Venus and has enhanced our knowledge of the planet's rotation period. Magellan image data have also helped the IAU to further refine the measurements for the rotation period of Venus and the direction of its north pole: 243.018 days; 272.76 degrees right ascension and 67.16 degrees declination.

GRAVITY STUDIES

Along with its other tasks, Magellan is attempting to measure precisely Venus' gravity field. In conjunction with radar and altimetry observations, gravity data will help scientists to develop a more complete model of Venus' interior.

Most geological processes on Venus — as on Earth — are either directly or indirectly driven by a process called convection that occurs deep in the planet's interior. Within a planet, the decay of radioactive elements heats material and causes it to rise toward the surface — where it then cools and sinks back into the deep interior. Also, surface features such as mountain ranges are formed by processes that originate inside the planet. To fully understand a planet's evolution, therefore, we must know what has happened and is still happening in the planet's interior. Gravity data can provide this information.

Gravity data help scientists to determine the thickness of the layers — such as the crust and the mantle — that



Located in an equatorial highland called Atla Regio, Sapas Mons is 400 kilometers across and 2 kilometers high. Two flat-topped mesas, which appear dark in this image, are seen at the volcano's summit. The sides of the volcano are covered with numerous overlapping lava flows, which appear to have erupted there instead of from the summit.

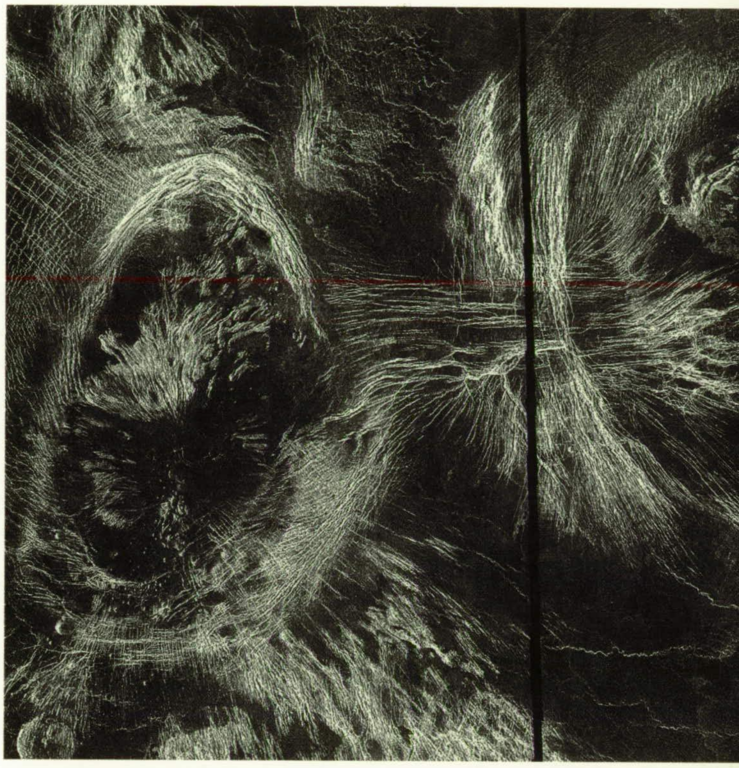
constitute a planet, and to interpret clues from the varying densities of material in a planet's interior. For example, thinner, less dense layers may indicate an area where hot material is rising.

Magellan itself is subject to Venus' gravity: The spacecraft's orbital motion is controlled by the planet's gravity field. "Large mass" areas — such as mountains — gravitationally attract the spacecraft, thereby causing it to accelerate. "Lesser mass" areas — such as large valleys or lowlands with less gravitational pull — cause the spacecraft to slow down. In addition, subsurface structures may affect the spacecraft's movement.

Gravity data have already shown a basic difference between the interior processes of Earth and Venus. For Earth, gravity data indicate that convective rising and sinking are not always directly related to surface geological features. On Venus, in contrast, surface features seem to be much more closely linked to interior processes — and may provide a "window" into the planet's interior.

Magellan's radio communication with Earth is the only link required for the collection of Venusian gravity data. Each time Magellan points its antenna toward Earth to transmit data, ground engineers can measure the variations in the spacecraft's orbital speed.

The best opportunity to acquire gravity data is when the spacecraft is closest to Venus. For the first three 243-day mapping cycles, however, that part of the orbit was devoted to radar mapping — with the antenna pointed toward Venus' surface. The most useful gravity data have since been acquired during the fourth mapping cycle — when the main antenna can be pointed toward Earth throughout each orbit.



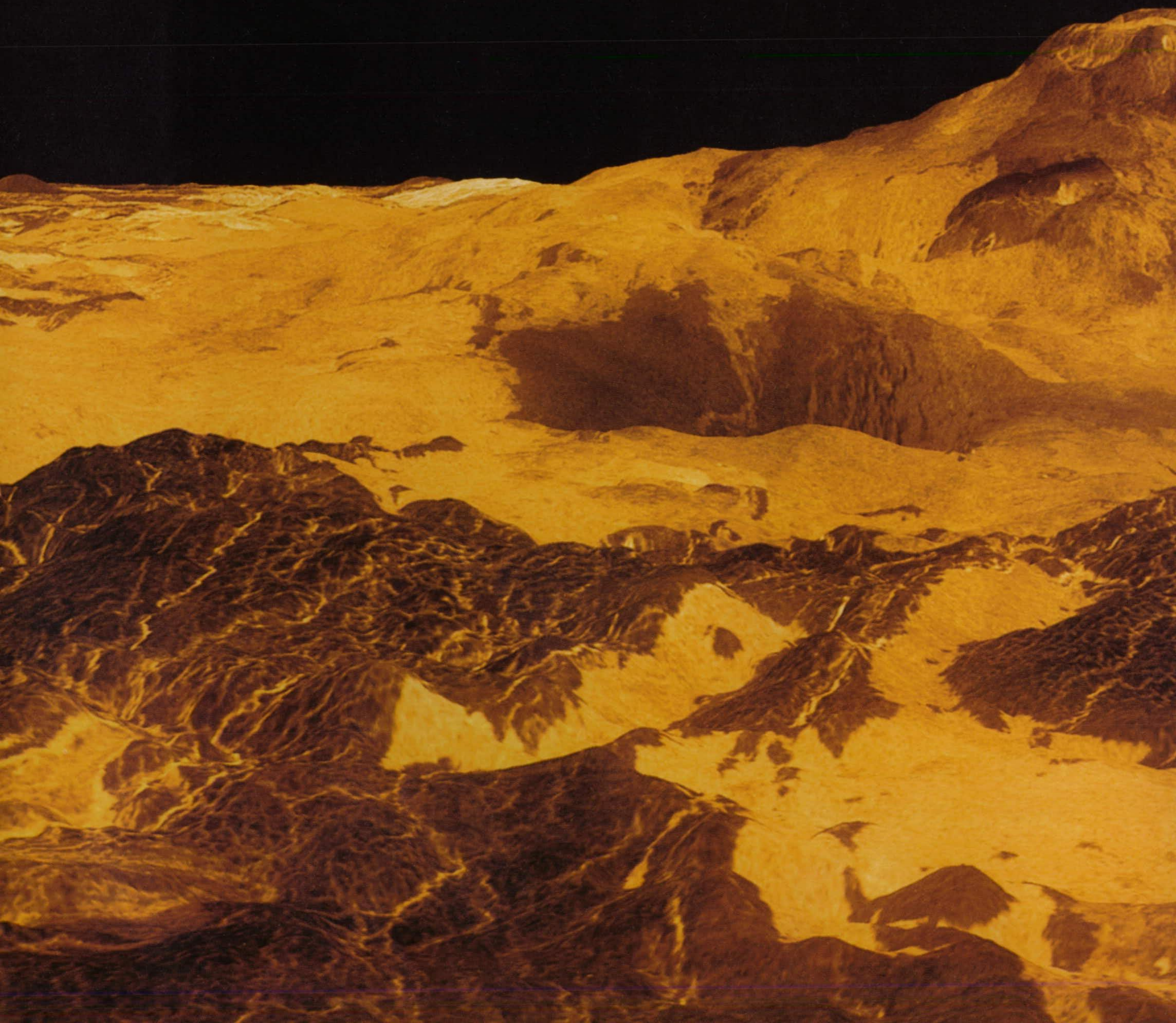
Bahet (left) and Onatah may have formed at the same time as hot material rose from deep in Venus' interior. Both coronae are surrounded by rings of ridges and troughs, while their centers contain radial features, volcanic domes and lava flows.

Radar Sensor: Seeing, Touching, Hearing

Magellan carries one science instrument — a radar sensor — that performs three distinct functions in Venus orbit:

Imaging — The radar sensor "sees" and captures detailed radar images. The radar transmitter fires a rapid burst of pulses through the large antenna, which is aimed to the side of the spacecraft's direction. Moving at the speed of light, the radar pulses strike the Venusian surface, return to the large antenna and are recorded on tape.

Altimetry — The radar sensor "touches" Venus to determine the height of features. The radar transmitter emits short bursts of microwave energy through the horn-shaped altimeter antenna, which is pointed straight downward.

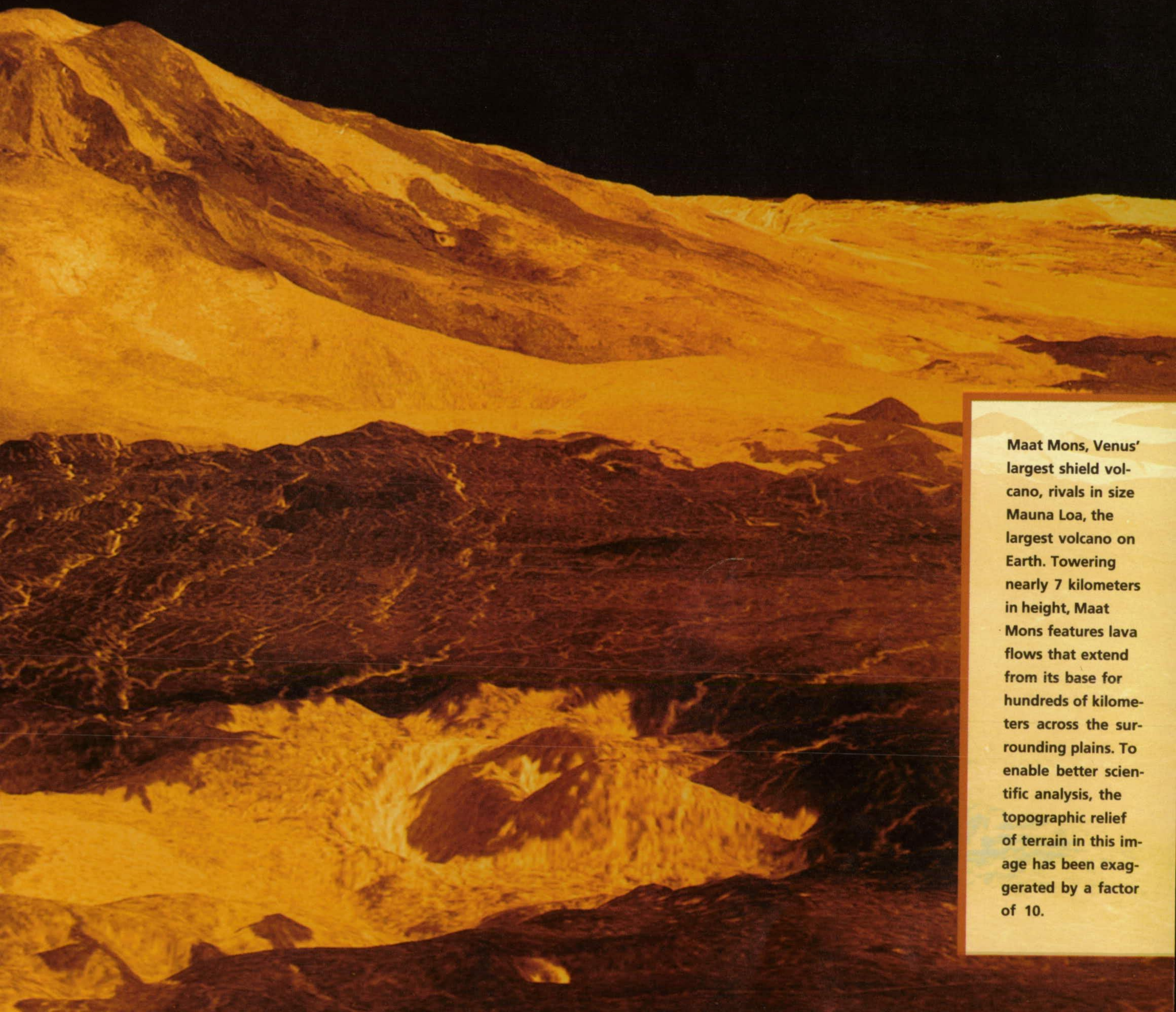


These pulses bounce back and are captured by the altimeter antenna.

Radiometry — The radar sensor "listens" to detect natural thermal emissions from the surface by passively receiving the thermal energy emanating from Venus' surface. Radiometry information provides clues about the properties of surface materials.

Completed in a rapid sequence that lasts less than a second, the three functions are repeated continuously for up to 37 minutes of each orbit while Magellan is closest to the planet. As the spacecraft moves away from the planet, the data are transmitted back to Earth.

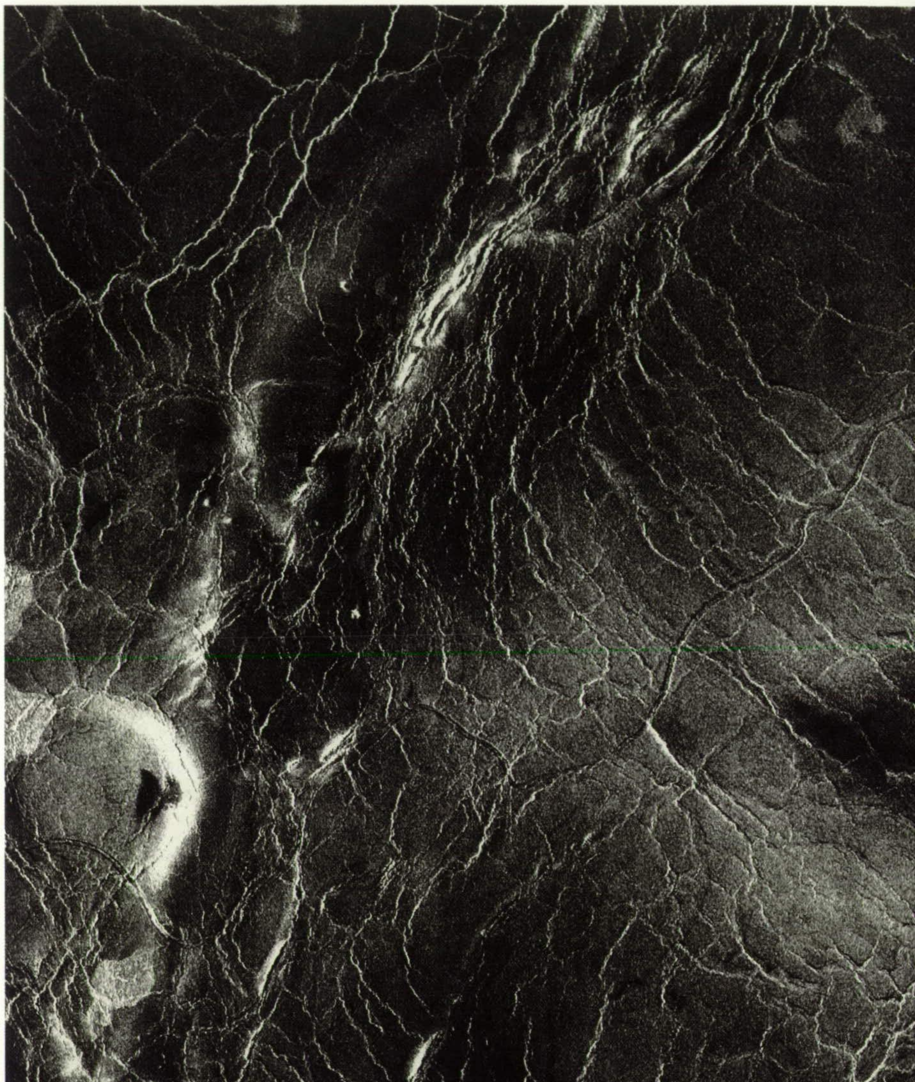
Computer processing at JPL transforms the Magellan data into photographic images. Orbital image strips, furthermore, are digitally "mosaicked" in order to create images of particularly large areas. The resulting images distinguish features from as small as 120 meters across in Venus' equatorial regions, where Magellan makes its closest approach, up to about 250 meters across near the planet's polar regions. In addition, the altimeter measures the height of surface features to within 30 meters. In all, Magellan's views of the Venusian surface are nearly 10 times better than those of any previous spacecraft.



Maat Mons, Venus' largest shield volcano, rivals in size Mauna Loa, the largest volcano on Earth. Towering nearly 7 kilometers in height, Maat Mons features lava flows that extend from its base for hundreds of kilometers across the surrounding plains. To enable better scientific analysis, the topographic relief of terrain in this image has been exaggerated by a factor of 10.

DATA PROCESSING & DISTRIBUTION

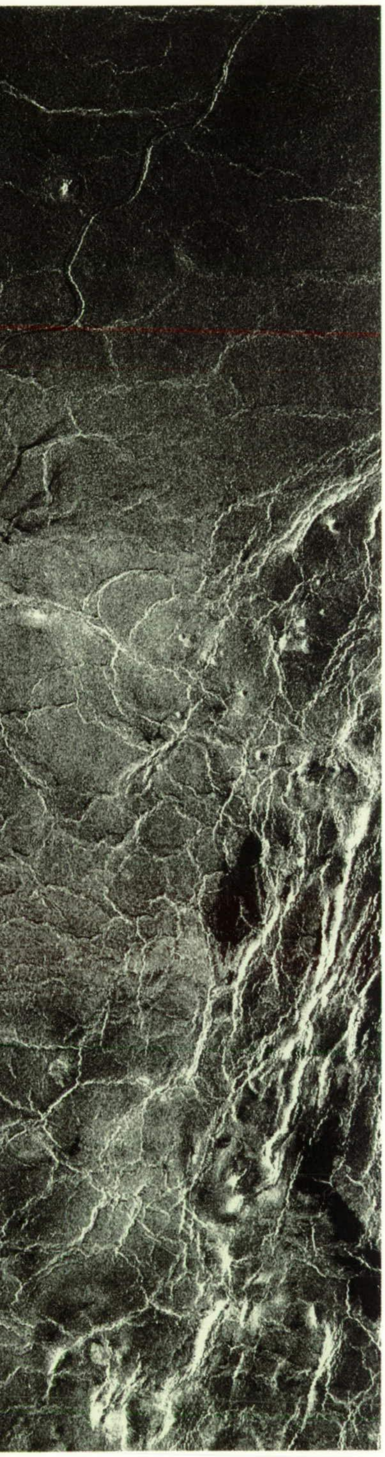
Magellan data have presented the largest planetary image processing challenge of any NASA mission to date. To meet this challenge, the project has developed new techniques for managing planetary mission data — Magellan is the first planetary mission to use a central facility to catalog and store all its mission data in a manner readily available for scientific analysis today and in the future.



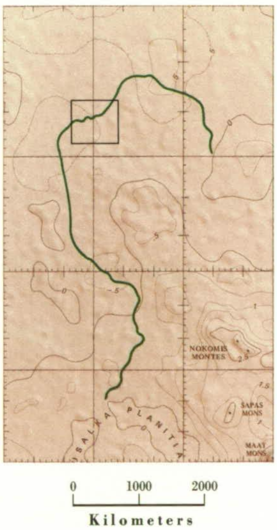
With the spacecraft transmitting data for two hours out of every three for several years, the amount of data acquired far exceeds that from all previous United States planetary missions combined. In the first mapping cycle alone, Magellan acquired 4 terabits (4 million megabits) of data, enough to fill approximately 35,000 computer tapes. Subsequent cycles have provided similar amounts of data. To illustrate the sheer volume of Magellan data — the tape from just one mapping cycle would stretch more than halfway around Earth!

ACKNOWLEDGMENT

The Magellan Project is managed for NASA by the Jet Propulsion Laboratory (JPL) of the California Institute of Technology. The Magellan spacecraft was built by the Martin Marietta Astronautics Group, Denver, Colorado. The Magellan radar sensor was built by Hughes Aircraft Company, El Segundo, California.



Stretching for 7,000 kilometers, Hildr Channel is the longest channel in our solar system. The 600-kilometer segment pictured is approximately 2 kilometers in width. Channels, common features on Venus' plains, were probably carved into the surface by hot, flowing lava. The accompanying map (below) shows that both ends of Hildr Channel have been covered by younger surface material — suggesting that the original channel may have been substantially longer.



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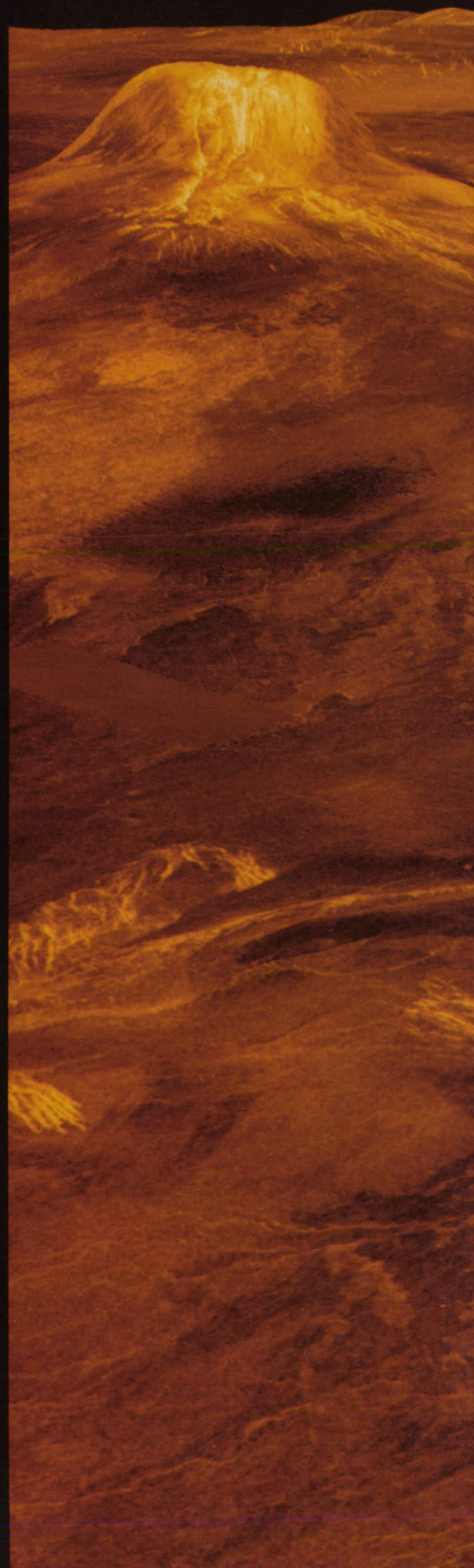
A Face Revealed

Magellan has added a stunning portrait — Venus — to our family album of terrestrial planets. The mission's high-resolution radar has created a global image that has greatly enhanced our understanding of Earth's "sister planet." We have also added to the store of knowledge from which we can reach a greater understanding of our own home. The views of the Venusian surface revealed by Magellan show that Earth and Venus are "fraternal" rather than "identical" twins. As is often the case with scientific endeavors, while Magellan has answered many questions about its subject, the answers have in turn led to important new questions — many unimaginable before the mission. Magellan has established a framework for the continued exploration of Venus. Future mission opportunities abound: Landed spacecraft to sample Venus' soil and measure seismic activity could uncover more about the planet's ongoing evolution; balloons set adrift in Venus' atmosphere could study atmospheric temperature, pressure and composition, revealing clues about atmosphere–surface interactions. Knowledge about each part of the Venusian environment is vital to our eventual understanding of the whole. For the future, Magellan has advanced NASA's program of planetary exploration — from the reconnaissance phase to a new era of detailed investigation of individual planets. For now, Magellan has revealed a face — the face of the morning star and the evening star — the face of Venus.



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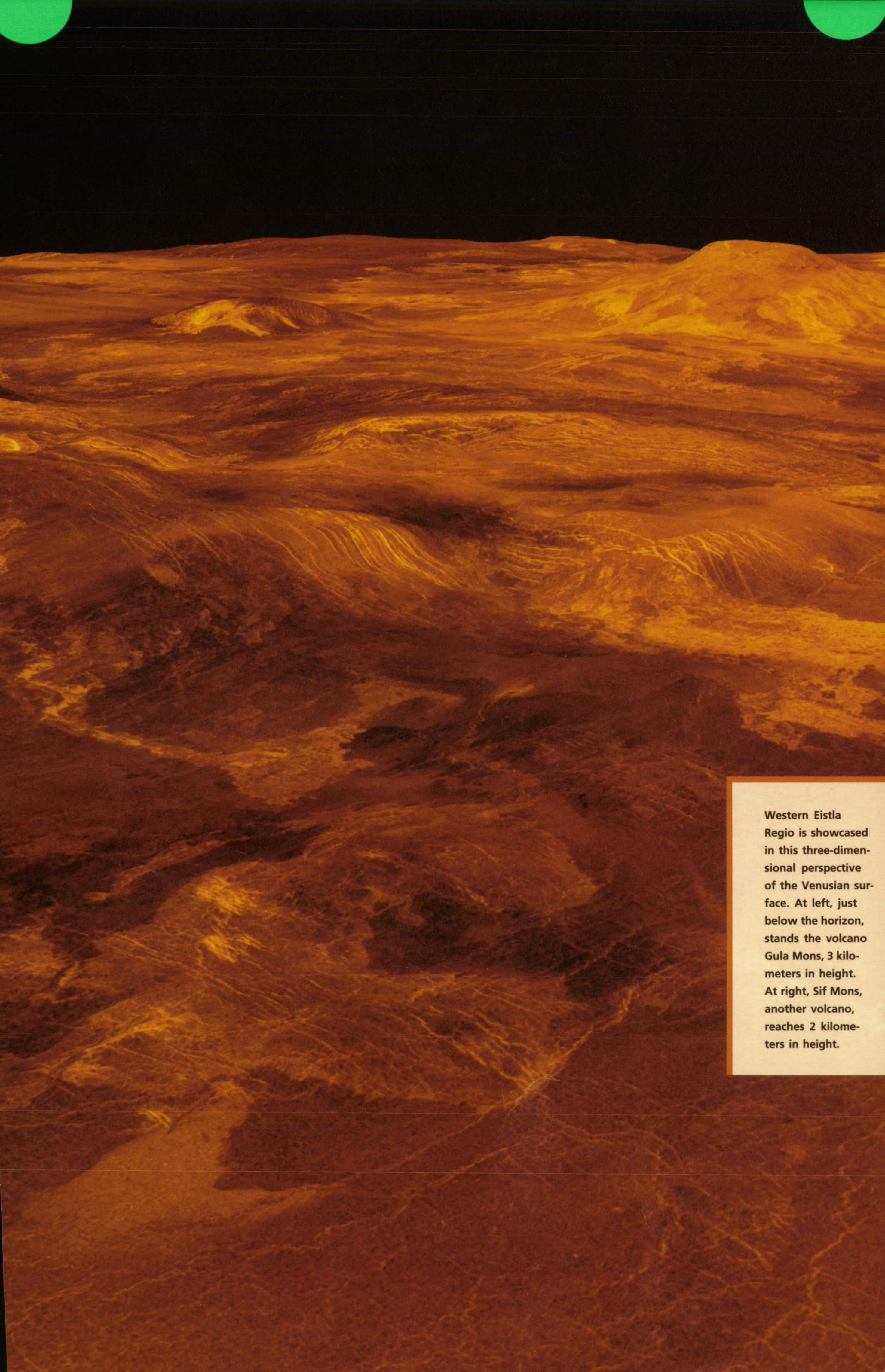

Western Eistla Regio is showcased in this three-dimensional perspective of the Venusian surface. At left, just below the horizon, stands the volcano Gula Mons, 3 kilometers in height. At right, Sif Mons, another volcano, reaches 2 kilometers in height.

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